

A DESIGN-BASED APPROACH TO TEACHING SUSTAINABILITY

by

Kim R Walter

B.S. University of Wisconsin Madison, 1994

M.S. University of Wisconsin-Milwaukee, 2002

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This thesis for the Doctor of Philosophy degree by

Kim R Walter

has been approved for the

Education and Leadership Innovation Program

by

Alan Davis, Advisor

Joanna Dunlap, Chair

Connie Stewart

Laura Summers

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Walter, Kim R (Ph.D. Educational Leadership and Innovation)

A Design-Based Approach to Teaching Sustainability

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ABSTRACT

We live on a finite ecological system, yet consume as though resources are unlimited. Current environmental data suggests many in the developed world are living beyond what the earth is able to sustain. The paradigms in which we operate continue to support a path of constant consumption that continues to exacerbate this problem. Technology educators can and should play a valuable role in working with students to question these paradigms through lessons that begin to engage students toward thinking about a more sustainable future.

Design-based instruction provides a framework for instructional practices that allows students to build problem-solving and critical thinking skills as they begin to understand deeper concepts related to sustainability. This study examined middle school students' understanding of sustainability after completing a design based unit. The study evaluated student work, concept maps, observations and pre-and post-tests to determine student understanding of sustainability. Instruction involved aspects of problem-based learning, design education and the use of technology.

Students were given an authentic problem of designing a sustainable home. As part of the design process, students conducted research on the factors and specific design components that would make a home sustainable. The main question guiding this study was "How can a home design project impact middle school students' understanding and

appreciation of sustainability?”

The findings suggest students demonstrated significant growth in understanding concepts of sustainability and were able to apply sustainable concepts in their designs. Eighty percent of students were able to meet or exceed rubric expectations on explaining the importance of sustainability. All of the students also demonstrated considerable growth in the understanding and application of sustainable solutions to their designs. They were able to propose authentic solutions to the problem and apply their research.

The form and content of this abstract are approved. I recommend its publication.

Approved: Alan Davis

DEDICATION

I dedicate this work to PATRICK DAY and MY STUDENTS.

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LIST OF ABBREVIATIONS

ESD Education for Sustainable Development
PBL Problem Based Learning
CHAT Cultural Historical Activity Theory

CHAPTER I

INTRODUCTION

The United States, with less than 5 % of the global population, uses about a quarter of the world's fossil fuel resources—burning up nearly 25 % of the coal, 26 % of the oil, and 27 % of the world's natural gas (World Watch Institute, 2011). World Watch further suggests that the average home size has increased by 38%, while the total number of people living in the home has decreased (2011). In the developed world alone, citizens consume 20-30 percent more than the planet is able to handle (Hales & Corvalan, 2006; Vitousek, Mooney, Lubchenco, & Melillo, 1997). Consumption rates are moving faster than the earth can replace the resources being used (Head, 2011). As the population of the planet increases, demand for resources will also continue to increase and available productive land will continue to decrease. Current levels of average consumption world-wide require 2.02 hectares per person, while Britain and the United States alone are using 6 to 10 hectares per person (Head, 2011). The United Nations' (1992) findings directly identify the cause of this unsustainable path as consumption and production, particularly in developed countries, that will ultimately lead to continued degradation of the environment.

Head (2011) states, “Energy consumption is central to our model of human development, and in designing and building these systems, we have created the hard wiring of a non-renewable fossil fuel resource-consuming society” (p. 21). Yet, the current political and economic discussions focus primarily on continued material growth. Consumption is seen as a right for everyone in society (Harper, 2007; Bush, 2007). The

tragedy of this thinking is a discourse that has compromised the environment and our health. Attention to the problem is dealt with "...as something to be considered only if forced to do so by threat of regulation or economic sanction. These paradigms are no longer viable or defensible from an ethical or moral standpoint" (Elshof, 2008, p. 134). This system of production to constant consumption has been created and therefore can be changed.

The United States operates under an economic paradigm that uses non-renewable resources ending in landfills, polluting and destroying the eco-system that provides life (Head, 2011). This very linear system does not work given the environmental constraints of finite resources on a finite planet. It is a consumption-driven model that designs for manufacturing-to-consumption and ultimately for the landfill through both planned obsolescence and perceived obsolescence (Grossman, 2006). Sustainability challenges the system of production-to-consumption as well as the assumption of continuous economic growth (Fraud-Luke, 2009). Educating about sustainability enables students to challenge these paradigms and equips students to propose ideas to address these issues. "Characterized by its combination of content, methods, and intended learner outcomes, the aim of sustainable education is to help students understand and respond to complex environmental, social, and economic issues in a way that promotes sustainable living" (Higgins and McMillan, 2006, p 40).

Sustainability is defined by the World Commission on Environment and Development (Brundtland Report) as "the systematic, long-term use of natural resources so that these are available for future generations" (1987, p. 43). This provides a working definition for the classroom. However, Fihlo, Evangelos and Pace (2008) believe the

definition should be constantly evolving and that Education for Sustainable Development (ESD) needs to be defined by questions that require a rethinking of educational traditions and norms to meet the needs of ESD. Education and teacher education programs must begin to prepare students for a sustainable future (Gross, 2000). Students today did not design or create the current paradigm. They are, however, active participants and consumers. Sustainability, as part of the curriculum, can help students understand their role in caring for the environment (Elshof, 2008). Technology classes provide an opportunity to address this challenge. It is imperative that education in and for sustainable practices plays a central role in technology education (Elshof, 2008).

Statement of the Problem

Limited research has been conducted to examine the nature of learning understanding of sustainability in technology education (Middleton, 2009). Additionally, many of the leading organizations charged with developing educational standards call for problem solving, critical thinking, and developing technology skills. They do not however address the need for understanding sustainability. The *Tech Tally*, a report by the U.S. National Academy of Engineering and the National Research Council (2002), categorized characteristics of a technology literate person in areas of knowledge, critical thinking, decision making, and technological capabilities. However, the *Tech Tally* does not include environmental or sustainability concepts in technological thinking, design and capability that are needed to address problems of today and in the future. The International Society for Technology Education (ISTE) and 21st Century Skills have also created technology standards and frameworks for education (ISTE, 2007; 21st Century Skills, 2008). These also do not mention the need for students to understand

sustainability concepts. Educating for understanding of sustainability concepts, in addition to problem solving and critical thinking skills, will help students to rethink the current economic and social paradigms. Education for sustainable development can empower individuals toward transformative actions that result in changes in world view (Pavlova, 2009). Given the reality of our natural systems, a change in consumption, i.e. a drastic change of everyday habits is upon us (Elshof, 2009). McKeown (2002) further states, “The challenge is to raise the education levels without creating an ever-growing demand for resources and consumer goods and the accompanying production of pollutants. Meeting this challenge depends on reorienting curriculums to address the need for more-sustainable production and consumption patterns” (p. 11). Components of successful sustainable education design have three main goals (a) students understand problems and issues for sustainable futures: (b) to promote awareness of sustainability through projects and activities, and (c) to use eco-design principles (Pavlova, 2009). The technology classroom provides an ideal setting for the teaching of sustainability concepts (Gross, 2000). Interestingly, the most educated nations also have the highest consumption rates (McKeown, 2002). Technology education for sustainability is a human created and directed activity whose purpose is to bring about purposeful change in student learning, teaching effectiveness, and program effectiveness in an exemplary way (Gross, 2000). Technology education and learning about sustainability allows for the fact that design problems are a new conceptualization of problem solving (Middleton, 1998).

Rationale and Purpose of the Study

I undertook this study to examine in detail students’ participation in this unit and their subsequent understanding of sustainability concepts upon completion. Several years

ago I introduced a unit on sustainability in a suburban middle school. The unit emerged as a central challenge for me as a teacher. In my view the unit had the potential of accomplishing the technology objectives of the course and teaching students essential knowledge about sustainability at the same time. The initial experience, however, did not meet my expectations, but met with enough success as the students were interested in the technology and did learn about sustainability to convince me that my expectations were not unrealistic. I decided to systematically study my efforts to improve the unit and document in detail the learning of the students as they progressed through it. As a work of action research, this study had the dual purpose of informing my own practice as a teacher using technology to teach about sustainability, and to explore with a wider audience the broader potential and implications of using design to teach about sustainability. The purpose of this study is to explore middle school students' understanding of the concept of sustainability within technology education as an effort to improve classroom instruction. The study used the case of a middle school technology unit to carry out this purpose. Sustainability is often a difficult concept for middle school students. Many students think of sustainability as structurally sound objects or eco-friendly products and recycling.

A further reason for this study is to address assumptions students and parents have toward sustainability. Most of the students begin this study not really understanding sustainability beyond being eco-friendly. Many of their parents don't agree with the discussion of this issue or that of climate change in the classroom, as both are often seen as a values debate rather than an issue on established knowledge. Given the climate change data and other environmental issues, it is imperative such issues be presented in

the classroom. Instruction should go beyond political controversy to alternative ways of addressing future problems while giving students tools to question and rethink the current paradigms.

This thesis evaluated student created solutions to sustainability problems in addition to instructional tools such as concept maps, observations and pre-and post-tests.

Instruction involved the use of the design process, concepts from problem-based learning, and the use of technology. Students were given an authentic problem of designing a sustainable home. As part of the design process, students conducted research on sustainability as it relates to home design. They had specific design factors and components to address. They used research to inform their design proposals as well as to enhance their understanding of sustainability. Aspects of problem-based learning and design-based instruction provided a framework for the learning environment, which is particularly well suited to leading students to a lasting change in both understanding and attitudes towards sustainability. This framework guided the overriding question of the research.

Research Questions

The focus of this research is on applying a problem based learning model on design based instruction in an attempt to develop a greater understanding of the subject matter, make connections across disciplines and build problem solving skills. The main question that will guide the research is, “How can a home design project impact middle school students’ understanding and appreciation of sustainability?” Questions that will help guide the study include:

1. What are middle school students’ attitudes and understanding of sustainability

- before and after a design unit?
2. Why are sustainable practices important?
 3. After completion, has the project impacted students' ideas about personal lifestyle choices in terms of consumption?
 4. What sustainable solutions do students propose for home design?
 5. How do students approach and try to solve sustainability issues in the architecture project?
 6. How did students apply sustainability ideas in their proposals, and why did they make those specific choices?

Preview of Methodology

The study involved action research. As a teacher and scholar, action research provides support for the instructor as researcher. Action research helps the instructor document context, procedures, growth, and theory to aide in developing and improving classroom practices (Fisher & Phelps, 2006). Action research conducted by teachers also offers a valuable contribution by “reflective practitioners” (Suter, 2006).

My questions for the study emerged from reflection on the unit related to classroom practice, student needs, and a specific focus on improving the lessons. This is supported by Cocran-Smith and Lytle (1990) when they discuss teacher developed questions; teacher developed questions come from areas in need of improvement and a combination of both theory and practice. Teacher research will force the re-evaluation of current theories and will significantly influence what is known about teaching, learning, and schooling. The study uses both quantitative and qualitative data to inform understanding. This is comparable to research tools used in other methods of study.

Qualitative data was comprised of teacher observations, evaluations of student created maps, concept statements and the final design solution. The final product included the design and a paragraph (concept statement) explaining the sustainability factors used in the design of the home. Students also created a concept map of their

learning throughout the process. These artifacts were analyzed for the connections students made as a means of understanding their learning.

Classroom observations were also recorded in a daily journal during at the end of each class. Observations and subsequent recordings included three components: (a) interactions that occurred with students including student questions, (b) teacher feedback from students' questions, (c) students' use of feedback in the designs.

The last component of data collection was conducting individual meetings with the students. I met directly with the students to discuss their grade and the ideas in their project. Students had to reflect on their designs, goals, problems that occurred, and their overall learning in small groups with the instructor.

Pre-and post-tests were administered to get an overview of student understanding of their learning prior to the study of the unit and then as a result of the unit. The goal was to examine the greatest student understanding and application of the concept of sustainability before and upon completion of the unit.

Evolving History of Design Unit in the Technology Classroom

Because of the continually evolving nature of the unit, action research supported data collection that lead to the improvement of the lesson. I initiated the unit for two main reasons. First, the current environmental paradigm needed to be taught, and research suggested the technology curriculum was a great avenue for addressing the concern. Second, I had a new opportunity to develop and create a more challenging curriculum since moving from a classroom designed around the students rotating through twelve different stations to a classroom with more computers. The additional technology

provided an opportunity to develop a richer, more challenging curriculum to meet the needs of the 21st century.

A characteristic of design research is that it is an interactive and ongoing process. Each revision of the design is based on an examination of the strengths and weaknesses of the previous version. In that sense, this project has evolved through an informal process of design research. I have been teaching the sustainability unit for seven years. It developed as I began looking for curriculum that challenged students to go deeper into a problem. Design problems challenge students to problem solve and allow for easy connections beyond the classroom. I also needed design problems that did not require high cost software. *Google SketchUp* was a cost-effective choice which afforded a wider range of possibilities in terms of design problems.

I originally started by giving students the problem: designing a sustainable home for a family of four, and then guiding them through the design process. This ever-evolving lesson started with me being very explicit about the design process. Students started with understanding the problem, researching and then creating proposals. Many of the original final designs demonstrated that students really wanted to just design a dream home, but with limited thought put into sustainability. I then began having students begin their research by going home and evaluating the spaces in their home. They listed what things were in their home and how often they were used. Students brought back their research and we discussed in a large group what was “needed” versus what was “wanted” in the home and then went on to completing research and proposals. However, the students often had difficulty applying their research to their designs, or were unwilling to do real research, or didn’t complete the homework.

I decided the research component needed to be more helpful to the students so I began digging for sources to help students see more examples. I located a design competition in Chicago where architects proposed sustainable home designs for low income housing. The article explained the thought process of the architects and an accompanying set of handouts to go over with students as part of the research aspect. I searched for resources and then had students complete web quests for their research component. This was difficult as there were very limited, kid-friendly resources on architecture and sustainability available for students. I tried working in *Inspiration*, a software program that enables the user to organize information in a web format. The students built webs of their research findings and even worked with them in large groups, but students still wanted to spend much of their time adding basketball courts and swimming pools to their final designs. It was evident that they were still not grasping the research or applying their research to their project.

I then started looking for sample graphic organizers that might help all students organize their research findings into a more useful format. I experimented with different types of notes, non-linear organizers like clusters or webs that help students connect ideas to thinking maps. The most effective seemed to be two column notes. Students could easily organize their research findings and quickly apply them to their home. The guide for the notes came from the *My Footprint* quiz, allowing for understanding of the problem in a simpler context.

Additionally, about this time I found *The Story of Stuff* video by Annie Leonard. This made the problem of sustainability more easily understandable for the students. The students connected with the images and questions in the video, thus making the design

problem authentic. I saw kids ask more questions after the video concerning why society continues on an unsustainable path. I brought in architects to discuss their work with the students and to help them make connections to what they were doing and to possible career choices. The architects gave the most valuable feedback on my lesson, there by altering what I needed to do to get the students to understand the problem. This connection within the business community was invaluable at helping fine-tune the lesson before and after each session to best help the students. They are, after all, experts in their field. After working with them I have changed the lesson and continue to make alterations as knowledge in the field evolves, and I get better at addressing the needs of the students.

The architects suggested narrowing the lesson to specific locations. I now give the students a choice of building locations. Such a focus challenges students to think more about actually applying their research based on a specific location. I have used *Google Earth* to mark specific locations that students must look up and then try to design accordingly. I have worked with students to think more about designing for a purpose that goes beyond sustainability, for a family for instance.

The architects would work with students on the size of their home as it related to sustainability. Students often had homes ranging from 2 inches to 2000 feet long. The architects measured the students' models. As a result, I had students measure aspects of a building and use those measurements in their home (for example the height of a story, height of a door, width of a door, and dimensions of furniture). This attention to detail helps students apply them to the design. When students were given the measurements

they did not apply them as easily as when they were asked to measure and record these measurements themselves.

I have also worked with students to design a home within a specific budget. The students must research the average family income and price of an average home and design with this budget in mind. The architects advised this as a way for students to think about addressing client needs rather than their own. I have no longer use this aspect up as part of the instruction, not because it wasn't valuable, but because the focus for the students was no longer on sustainability, even though that was still part of the design problem.

The architects have also recommended getting the students to think more about the design of their home. Sustainability can be addressed through design, an issue addressed in the solar home competition video the students viewed this past year. Placement of the home and windows are one example. The architects suggested getting students to utilize solar panels in the design, not just randomly place on the roof. As a result of their suggestions, I have spent more class time showing specific homes with design features that address sustainability.

The architects proposed having students write the concept statement. This makes the students articulate their goals and explain how they specifically addressed sustainability in their design. This has proved invaluable to getting students to discuss and be accountable for their thinking in their design and the justification for the purpose of their design. Another aspect suggested by the architects is to have students set a goal with their design, that isn't just creating a sustainable home, such as for a family or a place the student wants to live. The lesson itself is ever-evolving as more resources

become available. The lesson examined for the study added a research component for the students. Students had to search for two more additional website resources. They often found websites that are easier and more interesting for them to understand. Toward this end I chose to work with the school librarian and for searching and evaluating websites.

The goal of the project is to aid in conceptual change as it relates to sustainability concepts, help students build skills and apply research to their problem solving, and build problem solving skills and strategies. The role as a teacher scholar is to evaluate the degree to which students met these goals.

CHAPTER II

CONCEPTUAL FRAMEWORK AND REVIEW OF LITERATURE

Conceptual Framework

A framework for issues the curriculum needs to address in education for sustainable development (ESD) are provided by Filho, Evangelos, & Pace (2008):

Students should have qualities such as human values; perspectives such as respect and tolerance; a sense of caring for the environment and others, and the personal and vocational skills to be self-reliant and not become a victim of circumstances. Moreover, they need to understand the strategic issues facing them at the local and the global levels and how each of these issues regarding the environment, the economy and society's well-being are interdependent. In this context, fundamental skills such as critical and ethical thinking, problem-solving, consensus building and conflict resolution as well as the knowledge that science, business, and politics must work together are essential components of an ESD program. (p. 138)

Problem-based learning provides a guide for educating about sustainability in design-based problems as it guides students to toward conceptual change. The design process is a framework for students to understand a problem in depth. In this section I will discuss problem-based learning and design instruction. Finally, I trace the theoretical and philosophical roots of both problem-based learning and design instruction and their relationship to the sociocultural approach of Vygotsky.

The teacher plays a facilitator role as the students progress through the design process. Classroom practices that students will use include cooperative learning groups,

creating connections to what students already know, and connecting learning to the real world. As a result students will see growth in their understanding of sustainability, and the ability to apply this knowledge in their lives and to create solutions to problems they identify. See Figure II.1.

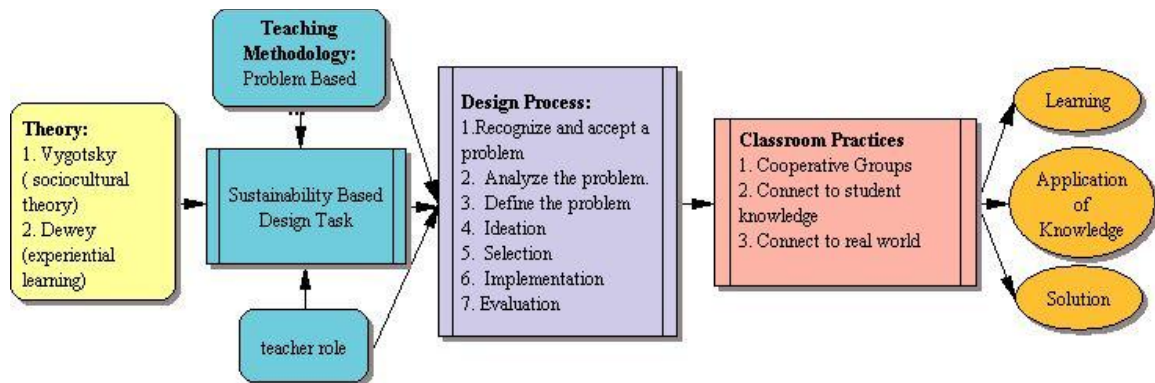


Figure II.1 Concept Map

Sociocultural theory and experiential learning inform teacher practice through the use of problem-based learning and design instruction.

Problem-based Learning

The sustainability unit draws on the traditions of problem-based learning and design education. While there are specific models and procedures for the use of problem-based learning this unit does not follow a particular refined model, but rather draws on important elements such as student-centered practices, having multiple solutions, reflection, evaluation, and teacher facilitator role. Students were left to use their own initiative and processes to arrive at their own unique solutions and were not graded on how well the model conformed to a specific outcome. They were provided scaffolding to address important aspects of the problem. In problem-based learning students are given a problem, issue or situation to address (Todd, 2009). Problem-based

learning (PBL) can be defined as,

... an educational format that attempts to simulate real life practice settings through pre-defined problem scenarios to encourage the discussion and learning of the experiences that emanate from practice-based problems. It is a method that fosters independent learning, encourages students to practically tackle perplexing situations and actively define their own gaps in understanding the problems in their realistic contexts, and enhances a more comprehensive as well as deeper understanding of the material rather than superficial coverage. (Eilouti, 2007, p. 198)

The PBL process has six dimensions according to Burrows and Kelson (1993) and Savery (2006): (a) develop a problem-solving approach to higher order thinking skills, (b) acquire knowledge that can be transferred to other situations, (c) direct their own learning, (d) develop skills to work with a team, (e) develop life-long learning skills, and (f) build habits for self-reflection and evaluation. Pierce and Jones (2000, p. 79) also support this, “Both contextual learning and problem-based learning can be seen as continua, moving from a low to a high degree of application.”

Ill-structured problems are those often encountered in real life contexts and are a predominant workplace skill (Jonassen, 2006). Problems create meaningful learning, particularly when structured to be active, constructive, cooperative and intentional (Jonassen, Howland, Marra, Crismond, 2008). The specific type of problem students are undertaking in this case is a design problem. Jonassen defines this as a problem that is goal directed toward the production of an object and has real world application that

requires structuring (2004). Problem-based learning allows students to connect and gain knowledge across disciplines (Boud, 1995). Problem-based learning goals are similar to the goals of design education (Eilouti, 2007). According to Eilouti (2007, p. 199), “Most design problems are known to be ill-structured and are based on multi-disciplinary knowledge and multiple information resources thus they are suitable for the multifaceted PBL model application.” Optimal problem-based learning lends itself to a focus on real world problems. It is learner directed where the teachers and students work together as researchers and learners. Students work directly with experts in the field through discussions, workplace visits, and evaluations (Pierce & Jones, 2000).

The design problem, designing a sustainable home, requires students to complete research to inform their designs and understand what knowledge they must obtain to complete a design. Students must understand what sustainability is, why it is important and how it can be specifically addressed in their designs. They also must create a design that a person would actually want to build or use. There isn't a right or wrong answer to the problem, leaving it ill-structured. Problem-based learning is also student-centered with small groups that are experiential and directed by the students, with the teacher acting as a facilitator (Hakkarainen, 2009). Design instruction works in a similar fashion. Students must engage in observation, identifying issues, framing problems, collaboratively working, discussing ideas, and presenting these ideas visually and verbally, as well as periods of reflection and critique (Davis *et al.* 1997). Sustainability problems are by nature complex and ill-defined requiring original solutions. As a result, sustainability problems are really design problems (Middleton, 2008). The design process and design problems lend themselves to students learning and developing these

skills. Design problems are complex and self-directed; they require collaboration and self-reflection as well as revision of ideas (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palinscar, 1991; Collins, Brown & Newman 1990; Harel & Papert, 1990; Kafai, 1996). It is also this meaningful learning that leads to conceptual change (Jonassen, 2006).

Sustainability alone is a complex problem (Elshof, 2008). It takes time to address and solve the problem. Kahane (2004) states,

Simple problems with low complexity can be solved perfectly well—efficiently and effectively—using processes that are piecemeal, backward looking, and authoritarian. By contrast, highly complex problems can only be solved using processes that are systemic, emergent and participatory. (p. 32)

The best instruction for sustainability involves meaningful change in student learning, exemplary problems, and effective teaching (Filho, Evangelos & Pace 2008). Problems related to sustainability do need to be integrated across subject matter and involve students in multiple skills (Filho, Evangelos & Pace, 2008). Problem-based instruction provides learners a better understanding of their learning. Jonassen (2004) states,

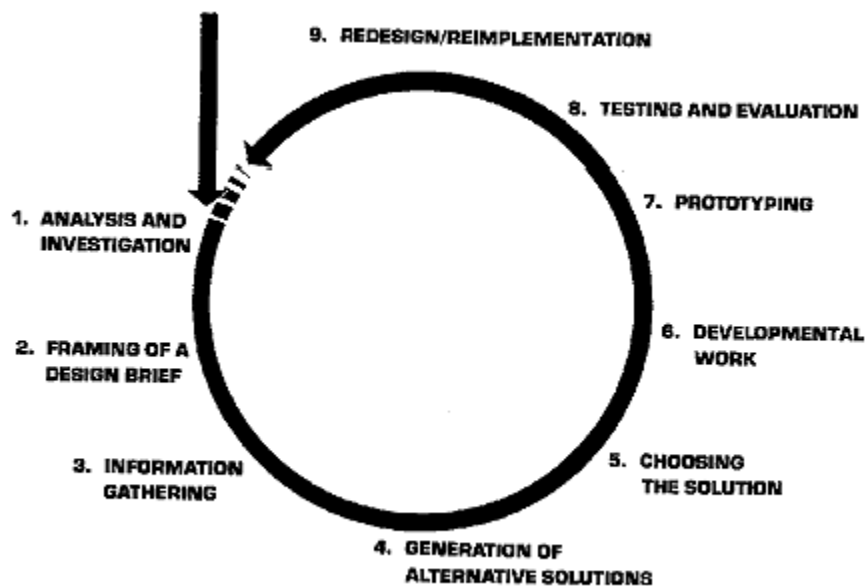
Students who memorize information for the test usually retain less than 10 percent of the whole curriculum, so 10 percent of the whole curriculum (100 percent assuming that the teacher or trainer can cover the whole curriculum) yields a 10 percent learning outcome (and is probably less than that). In a problem-oriented curriculum, students may cover only 50 percent of the curriculum, but they understand and remember 50 percent of what they learn, yielding a 25 percent learning outcome. (p. 2)

The Design Process

Problem-based learning is effective for teaching architectural design (Eilouti, 2007). Design education is an approach that uses aspects of problem-based learning (Gijssels 1996). Characteristics of problem-based learning include ill-structured problems based on integration of knowledge thus lending itself well to inform and improve design education (Dabbagh & Doss, 2013). Design education and the design process provide a framework with which to structure the learning environment when learning to solve problems and comprise some of the same characteristics. Design instruction also offers the opportunity of learning and problem solving to address a technology environment of exponentially expanding information, needs of the community and uncertainty in a rapidly changing society (Davis, 1999). Design is inherently not an object, but rather it is a form of inquiry (Davis, Hawley, McMullan, & Spilka, 1997). Design-based problems in which students participate often relate to their lives, school, or community (Marschalek, 2008).

Students work through the design process as they attempt to solve problems. Students are guided through the design process defined by Davis, Hawley, McMullan, and Spilka (1997, p. 2) as, "... a creative counterpart to the scientific method, and it presumes there is more than one right solution to any problem and many paths to each alternative." The design process develops fluency in images, words and thinking (Kimball, Stables, Wheeler, Wosniak, Kelly, 1991). Students learn to recognize and understand that the problem really does exist and are willing to attempt to correct it. The design process requires students get to know the problem, understanding the main issues of the problem in order to define it. Once students are able to understand the problem,

they begin research into solutions. The research informs their ideas and they begin to generate solutions to the problem. After examining and evaluating solutions, students must select the best possible way to solve the problem. They then put their idea into action by creating a prototype. Finally, students evaluate their design by determining the effectiveness of a solution, thus making changes as needed. (See Figure II.2 for a diagram of the design process). While the process is cyclical it is also on-going, requiring students to often go back to research and rework ideas. One of the major differences between the design process and the scientific method is the former is the cyclical nature. Students must evaluate and make changes throughout the process. They also do not start with a hypothesis in the design process. Rather, they start with a problem.



(Kimball, Stables, Wheeler, Wosniak, Kelly, 1991)

Figure II.2 The Design Process

The design process is a cyclical process.

A simplified version of the design process is used with the students, (see figure II.3). The simplified version is easier for students to understand and addresses the need for continuous evaluation of ideas. Because the process is also cyclical, the terms are easier for students to understand and evaluation of their ideas is on-going throughout the project.

Literature Review

Design serves as a framework for instructional practices that guides students through the problem solving process. Problem-based learning informs the role of the instructor and role of the students. Design as an instructional framework is rather progressive, particularly with a specific focus on reform (Roth, 1998). Design-based instruction contains real life learning as well as activities that are collaborative and make connections across disciplines (Brown, 1992). An important factor in design education that is similar to problem-based learning (PBL) is its authenticity to real world tasks and students assuming an identity as an architect. As a result of the connection to real life problems students begin to perceive their actions related to a future career (Barab & Dodge 2008). This connection to real life aides in developing life-long learning skills, reasoning, and application of knowledge (Grabinger, Dunlap, & Duffield, 1997).

Dialogue and Learning

A key component to learning emphasized by both Vygotsky (1978) and Dewey (1934) is the role of dialogue in the learning process. Dialogue, particularly language, is a key to cognitive development, through common problem solving experiences (Vygotsky, 1978). Students must engage in active learning through dialogue and

problem solving (Dewey, 1929). Dialogue originally occurs with those taking care of the child, but as the child grows and develops he or she takes a larger role in problem solving. Language becomes the primary tool of intellectual transformation as children mature (Vygotsky, 1978). When children problem solve, they demonstrate attributes of dialogue (Vygotsky, 1979 & Wertsch, 1980). Children ask questions and find answers and internalize this discussion. Children often collaborate with an expert individual. In the case of the classroom, it is most often the teacher or selective classmates. A classroom contains continuous interaction between teachers and students, who are defining and being defined by their learning experience (Wertsch, 1998). This allows learners to participate in activities that are at a higher level than they would be able to accomplish on their own.

Problem-based learning environments allow students to interact with the subject matter and other learners, concepts defined in a successful Education for Sustainable Development (ESD) program. Learning needs to occur in a situational context that allows for interactions and struggles in thinking, either through individuals, artifacts, ideas, tools or problems (Hung & Wong, 2000). Mishra and Girod (2006, p. 49) state, “At the heart of design is interplay between theory and practice, between constraints and trade-offs, between designer and materials, and between designer and user/learner.” It is with this dialogue that the learner creates meanings, defines ideas and begins to understand (Dewey, 1934). Students who interact with the subject matter are able to make connections beyond the classroom. This kind of interaction creates an ideal experience for the student.

Learning also occurs through the use of cultural tools (Vygotsky, 1978). He states that “Every function in the [individual’s] cultural development appears twice: first, on the social level, and later, on the individual level; the first, between people (interpsychological), and then inside the child (intrapsychological)” (Vygotsky, 1981b, p. 163). This function of cultural development allows for learning through large and small group dialogue, decisions students must make in terms of sustainability while designing, and potentially the individual decisions in sustainable choices the students make as consumers. “This form of learning is critical when dealing with sustainability issues due to the fact that individuals have pre-existing knowledge that needs to be examined on a deeper level for it to be altered (Shapka, Law & VanWynsberghe, 2007, p. 108).”

Experiential Learning

Design instruction and sustainability education also draw on the historical tradition of experiential learning introduced by Dewey. Students thrive when they are able to participate in the curriculum (Dewey, 1938). Design based learning environments allow students the ability to get involved in addressing the problem, thus creating an experience toward a solution. People are impacted by their experience (Dewey, 1938). Since students are impacted by their experiences, providing an opportunity for students to challenge and question established patterns through hands-on experience is invaluable for their continued growth. This is supported by Dewey (1938, p. 48) “The formation of enduring attitudes, likes and dislikes, may be and often is much more as more important than the spelling lesson or lesson in geography or history that is learned.” Education is a continual construction of experience (1897/1938). Kolb and Kolb (2008, p. 4) state, “learning results from synergetic transactions between the person and the environment.”

Stable and enduring patterns of human learning arise from consistent patterns of transaction between the individual and his or her environment.” This is further explained by Mishra and Girod (2006) when they state,

As the individual acts on the environment, the environment also acts upon the individual. Inquiry and learning, like design, are not simply about understanding and assembling materials. They are fundamentally about ideas and transforming oneself and the world through the process of working with those ideas. (p. 48)

Helping students understand sustainability and applying these concepts is an attempt at establishing enduring attitudes. Design also requires that learners determine the essential components of an idea and then represent those ideas (Mishra & Girod, 2006). Mishra and Girod further state when students develop new ideas, they develop new ways of understanding and acting within the world. An idea means one is more fully alive with thought, feeling, and action. Idea formation and creation goes beyond attainment of information, rather it is empowering (Mishra & Girod, 2006).

This actual process of working toward understanding is also important. Kolb (1984) presents a cyclical model of experiential learning, consisting of four stages (a) concrete experience (b) reflective observation, (c) abstract conceptualization, and (d) active experimentation. Developing solutions to a design-based problem requires students to apply the research and understanding they have developed through these processes. Creating a proposal for a sustainable home creates an experience for students to question their current paradigms. Students must research, propose, experiment and evaluate their solutions as a part of the process. Kolb (1984, p. 38) states, “learning is the process whereby knowledge is created through the transformation of experience.” It is

through this experience that students are led to find sustainable solutions to current issues in sustainability. With these solutions, students will learn to understand and apply sustainability concepts beyond the classroom.

Design instruction offers the opportunity for dialogue within the problem. It offers the opportunity for students to make choices between theory and practice, constraints and trade-offs, materials and design, as well as the designer and users (Mishra & Girod, 2006). With this ongoing discussion and dialogue, meanings and artifacts are defined and understood (Dewey, 1934). Students must also understand the essential qualities of an idea and represent their ideas for an audience. New ideas are more than thinking about the world in a different way; they are about having a different way of being in the world (Mishra & Girod, 2006). To have an idea is to be more fully alive with thought, feeling, and action (Dewey, 1934). It is to have an “energy-for-action” that is directed by thought and fueled by emotion (Mishra & Girod, 2006). “The having of a new idea is more than the acquisition or application of information. It is critical to have students work with ideas that are inherently empowering and generative” (Mishra & Girod, 2006, p 48).

Relationship to Sociocultural Concepts of Learning

Challenging students to problem solve is further supported by the theoretical work of Vygotsky. Children learn through participation in activities and within social processes (Vygotsky, 1978). Design-based activities allow students a forum to participate in a problem through experimentation, interaction with others, and the opportunity to try out multiple solutions. Students are playing non-traditional roles in this project. They are the researchers, developers, and creators of solutions. They work

in cooperative groups and as a result are developing critical thinking and conversational skills. Adults need to engage children in tasks that challenge them, initially too difficult, then provide the necessary support to aid in accomplishing the task. This is often defined as the “zone of proximal development” (Vygotsky, 1978). Instructors can help guide students through a task, continually helping students improve their skills. Project-based and problem-based learning environments aide students in developing knowledge as needed to solve problems. Problems are often above their current skill level or development level. The teacher can facilitate student learning through the problem. In turn, students will ask questions or attempt to gain knowledge based on information they believe to be missing (Vygotsky, 1978). The ideal learning situation is tailoring instruction to the needs of the student based on an individual’s ability and cognition level (Hung, 2001).

Students will also seek out experiences in the zone of proximal development that can be enhanced through cooperative rather than individual tasks (Scardamalia & Bereiter, 1991). Children working in cooperative environments are thus creating a social context. In these contexts mutual relationships are required for learning, knowing, and understanding to take place. As students participate in design problems, students must organize and analyze information. They must work both independently and within teams to create viable solutions to problems as well as conduct research. Students must present ideas, negotiate, defend and compromise in the process. As students participate in these kinds of interactions, they are developing, “new intellectual tools and patterns of collaboration” (Engstrom, 1999, p. 31). They are also creating and participating in experiences.

Students are using various tools, but also adapting and changing the tools as needed to complete the tasks. Transformation of the tools and how they are used and interplay between the various elements constantly lead to the various new outcomes and knowledge being created (Engstrom, 1999). Cultural Historical Activity Theory (CHAT) expands on the model: “...Actions and the goals they accomplish are the dominant features in human consciousness during active engagement with our world (Roth & Lee, 2007, p. 201).” Activity that is directed toward goals, in the case of design education, goes beyond activities that keep students busy. Design activities allow students to become involved and engaged beyond the classroom. In design-based classrooms, students are required to work and think like designers. These activities, Roth and Lee (2008) believe, would promote the creation and replication of culture and its connection to the built world, thus sustaining the culture and as well as the individual (2008). The students, like graphic designers or industrial designers, are subjects of activity systems collectively understanding the motive and goal (Engstrom, 1999). Problems are authentic and require an understanding across disciplines. Students working in a collaborative team will construct knowledge in an educational setting. The teacher functions as a guide with the learners through the process (Davis, Hawley, McMullan, & Spilka, 1997).

Students learn in the context of their cultural environment, through social interactions and experiences, and are continuously learning. Bereiter (1994) has defined this process as unintentional learning. It often means in the context of the classroom that students aren't always learning the objectives teachers have set forth in their lessons; on the contrary in many cases they are learning more about the structure of school and

teacher expectations (Smith, 1998). This is partly due to the focus on skills students can demonstrate on achievement tests (Bereiter, 1994). Tasks and skills are often disconnected from one another. Students study science in one classroom and then move onto a math or language arts classroom, with little discussion of the relations between the subject matter. Design connects learning across disciplines and domains (Friedman, 2000). Students must also draw on a variety of resources to create a variety of solutions to problems (Davis, Hawley, McMullan, & Spilka, 1997). As students participate in design problems, they are intentionally learning since they are building knowledge through experience and research.

Design as Inquiry

Often thought of for use only in an art classrooms, design-based problems are a catalyst for learning (Davis, Hawley, McMullan, & Spilka, 1997). Design tasks and the design process focus on real world projects and problems that often connect learning to the community. Design-based tasks allow the educator flexibility in methodology, such as cooperative groups and technology as a tool for learning. Design offers the opportunity of learning and problem solving to address a technology environment of exponential expansion of information, needs of the community, as well as the ability to address uncertainty in a rapidly changing society (Davis, 1999).

Design surrounds us. The homes we live in, products we use, information we consume, and even the environment we interact in are all designed and shaped (Davis, Hawley, McMullan, and Spilka, 1997). The design of objects is not new. Humans have created tools and objects for thousands of years to address problems. However, viewing design as an activity is a fairly recent phenomenon (Naveiro & de Souza Pereira, 2008).

As we have become a wealthier society, design has taken on new importance. A larger range of goods and services is available and in larger quantities than ever before (Friedman, 1991). Societies make choices in the items purchased, in how their time is spent or even in the information consumed; each choice is often determined by their value system. Since design has produced a more comfortable lifestyle, it has not been of little cost. The products consumed and the environments created have come at a societal and environmental cost. However, it is also design that can create solutions. Design can and will contribute to the future and is one of the fastest growing industries (Pink, 2007).

The subject of design has been a focus of technology education in the United Kingdom and is becoming a focus in the United States as well (Lewis, 2008). Design allows for open-ended problems with multiple solutions and strategies for solving problems (Lewis, 2008). Optimal problem-based learning lends itself to a focus on real world problems. Design is a process that requires thoughtful planning (Friedman, 1991). This process requires the understanding of several domains: the human world, learning, artifacts, and the environment (Friedman, 1991). Design and design problems force students to think across disciplines for creative solutions (Davis, Hawley, McMullan, and Spilka, 1997). According to Marschalek, design can be categorized into four basic areas: (a) Object design is the design of everyday things. (b) Information design is the creation of web pages, brochures, and other media. (c) Environment design is of places and spaces such as parks, landscapes, and interiors. (d) Experience design is the design of events such museum exhibits, theme parks, concerts and more (2008). For the purpose of the research students are participating in environment design.

Students in design-based classrooms engaged in higher-order thinking skills more often than in traditional classrooms (Walmsley, 2003). This is further proven by Mishra and Girod when they state,

Design activities create opportunities to learn about the nature of inquiry itself.

First, design forces students to pay attention to the process and consequences of their actions. Second, students learn to appreciate the nonlinear, often messy nature of inquiry. Design tasks are often ill-structured and afford many viable solutions. This perspective on knowledge and inquiry is quite different from the epistemological illusion typically found in classrooms, where problems are well-defined with clear-cut solutions. (2006, p. 48)

Design is a social activity that requires students to communicate and understand the experiences of others. Students must generate and negotiate ideas while they share their knowledge with others to accomplish the task (Mishra & Girod, 2006). Even more important is that design requires students to gather data, conduct research, and represent their findings. This forces them to go beyond the classroom walls.

Knowledge Building

Learning and the creation of knowledge is defined by Bereiter (1994) with the term knowledge building. The creation of knowledge is often seen in creative businesses and among practicing scientists (Scardamalia & Bereiter, 1996). Knowledge building by students themselves is the most effective for transformational change and growth.

Students who actively build knowledge specifically in design are able to define gaps in understanding and build comprehension for themselves (Eilouti, 2007). Schools and

classrooms that emphasize the building of knowledge are highly successful. Classrooms that foster transformational thought for all participants, teachers and students alike are exceptional classrooms (Bereiter, 1994). Knowledge building classrooms focus on authentic tasks, facilitate communication and emphasize the contributions of those involved rather than competition. Learning tasks that occur over time also provide a rich learning environment (Barab, Dodge, Thomas, Jackson, & Tuzun, 2007). Students must also develop skills to enable them to work together and apply cultural knowledge to specific activities (Hakkarainen, 2009). When tasks are structured with the learners as the focus, students have the opportunity to be knowledge builders. They are able to build and create connections that lead to conceptual change. Inquiry-based tasks that are student directed increase knowledge building (Barab et al., 2007). It is difficult to separate the knowing and doing from the creative aspect of practice (Hakkarainen, 2009).

Students are also building expertise as they follow the design process. The building of expertise requires tasks to get more progressively complex (Bereiter, 1994). Inquiry-based tasks that are student directed increase knowledge building (Barab et al., 2007). Learning can also be defined by Lave and Wenger (1991) by knowing. Knowing is an act that is not static, but rather interactive. Knowing requires interacting with others over time. This idea is further described by Barab, Hay, and Lynch (2001, p. 68), “Becoming knowledgeably skillful, from this perspective, is characterized by an individual’s increasing potential to build and transform relations with the material, psychological, and social world.” Because design-based problems are authentic, students motivated by real world problems will easily make connections.

Scaffolds for Problem-Based Learning

Middle school students often struggle with research. Scaffolding can be used as a tool to help students construct knowledge (Cho & Jonassen, 2002). Scaffolding as a tool allows instructors to help students organize information and build connections.

Scaffolding can be defined as metacognitive strategies, conceptual, or procedural aid that enable students to develop a skill that might be difficult for them to complete unaided (Hamilton et al., 1999; Wood, Bruner, & Ross, 1976). The goal of scaffolding is to meet the needs of students at specific points in a problem and often requires more capable facilitators (Saye & Brush, 2002). The context of PBL supports collaborative knowledge construction with the use of scaffolding and can change how students interact with each other through transformation of the process and students' articulation of thoughts (Kim et al., 2007; Lin et al., 2003). Scaffolding helped college and middle school students distinguish between good and poor arguments (Belland), approach argumentation effectively (Belland), and produce coherent arguments (Bell, 1997; Cho & Jonassen, 2002).

Scaffolding is also a form of dialogue. It is this dialogue that allows the learner to participate in increasingly difficult activities that they may not fully understand (Palincsar, 1986). Palincsar (1986, p.75) further states, "The hallmark of scaffolded instruction is its interactive nature. There is ongoing interplay between teacher and learner in the joint completion of a task." This is the teaching and learning process (Wertsch, 1980).

Graphic Organizers and Learning

The value of graphic organizers to enhance learning in design education is an important outcome of this study. New learning builds on previous knowledge and experience, and it benefits students become highly aware of their existing knowledge before embarking on a new learning experience. Like Dewey, Ausubel (1968, p. 217) believes that experience is a factor in learning: "Existing cognitive structure, that is an individual's organization, stability, and clarity of knowledge in a particular subject matter field at any given time, is the principal factor influencing the learning and retention of meaningful new material." Ausubel further states, "It is also in its own right the most significant independent variable influencing the learner's capacity for acquiring more new knowledge in the same field" (1968, p. 130). Therefore, a "cognitive structure that is clear and well organized facilitates the learning and retention of new information" (Ivie, 1998, p. 35).

Graphic organizers are one set of cognitive structures or tools that help students organize information and aid in creating and building knowledge. Graphic organizers offer visual models that equip teachers and students with tools, concepts, and language to organize, understand, and apply information (Gallavan & Kottler, 2007) as well as assist learners in organizing information so that is understandable and useful for the learner (Meyer & Stull, 2007). Graphic organizers allow students the opportunity to guide their learning, create meaning, and use their information with others (MacKinnon & Deppell, 2005). Using graphic organizers, whether student generated or predetermined helps students understand new information (Mayer & Stull, 2007). The degree of difficulty and

level of the learner do play a significant role in the most effective method, student generated or a predetermined organizer (Mayer & Stull, 2007).

CHAPTER III

METHODS AND PROCEDURES

Methods

The main research question guiding this study is: How can a home design project impact middle school students' understanding and appreciation of sustainability?

Students were given a design problem: They must design a sustainable home for a family based on a specific location. Students worked through the design process. Students conducted research to understand the problem in depth from its importance to making their design sustainable.

The study employed an action research format. Action research is a systematic approach for teachers and other school related personnel with an interest in teaching and learning to conduct research and gather data about student progress (Mills, 2003). Action research examines a problem systematically and relates practice to theoretical considerations (O'Brien, 2001). Action research conducted by teachers offers a valuable contribution by "reflective practitioners" (Suter, 2006). The use of action research by instructors allows for the applied use of an intellectual model that rests in continuous improvement of teaching techniques and student learning (Young, Rapp, & Murphy, 2010). Action research allows the instructor to examine methods and increase knowledge toward improving classroom curriculum and learning (Kemmis & McTaggart, 1982).

Teachers can and need to take an important role in research. Teachers as researchers, Banks states, "become not only active in improving the learning experiences of their pupils but also critical of educational policies, materials or syllabus which affect their work" (2003, p. 314). Banks further discusses that when teachers take an active role

in research and data collection, it is “more reliable and any decisions made will be more valid” (2002, p. 315). While the focus of action research is not on hypothesis testing, it does meet the criteria of the scholarship through the “systematic reflection on teaching and learning made public” (Illinois State University, 2012).

Data collection included both qualitative and quantitative measures. The quantitative aspect evaluated student growth in their understanding of sustainability from the beginning to the end of the assignment using a pre-and post-test. The qualitative component examined students’ construction of knowledge related to sustainability, actions related to their application of sustainability in their designs, and connections they made beyond the project. Data were gathered from student final products, student-created concept maps, student reflections, architects’ feedback and teacher observations.

School Setting and Participants

This study was carried out in a middle school of 7th and 8th grade students in a large suburban district. The school population is largely middle to upper middle class students with some diversity in respect to socioeconomics and culture. The study was conducted in the technology classrooms. The technology class was an elective class that ran for a trimester or a total of 12 weeks. The specific classes being studied were two 8th grade technology classes. The classes studied consisted of two groups, each of twenty-five to twenty-seven 8th grade students ranging in ages from 12-14 years. Two students declined to be part of the study. The total number of students participating in the study was 50. One difficult issue occurred during the course of the unit studied. Eight of the 50 students were absent for a week during the unit. Four of those students were absent the final week of the unit.

Instructional Practice

The project began with the use of the design process. A simplified version of the process called the Design Loop by Hutchinson & Karsnitz (1994) was used with the students (see figure III.3). Students begin to understand a problem in stage one. Students must recognize a problem really does exist and be willing to attempt to correct it. In stage two, students must really get to know the problem. It is essential that students understand the main issues of the problem in order to define it. Here they begin to conduct research about the problem.

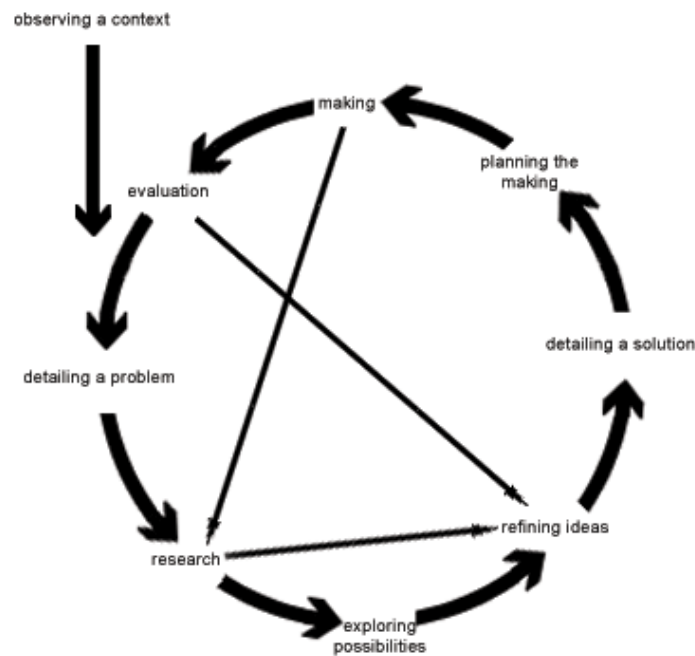


Figure III.3 Design Loop

The design loop simplifies the design process, making it more accessible to students.

In stage three, students begin to conduct research related to possible solutions. They then begin to formulate ideas to solve the problem and search out multiple solutions. In stage four students begin to formulate and plan out their ideas. They also

must evaluate their ideas during this stage and make adjustments as needed. Stage five requires the students to provide a detailed solution to their problem. Students must select their best idea to address the problem. In stage six students begin making a plan for creating their final solution. In stage seven the students work to create their final proposals to the design problem. This stage also requires them to conduct further research as needed and adjust proposal accordingly. In stage eight students evaluate and reflect on their work. This can be done individually, in groups, or with professionals in the field. Students must determine effectiveness of solutions and effects of results.

The project began with the first component of the design process: detailing the problem as outlined using the design loop. Students began this part of the project by watching the video, *The Story of Stuff*, www.storyofstuff.org, (Leonard, 2007). They discussed the current paradigms seen in the video and how these were created. They then discussed the implications of a different paradigm offered in the video. Students were given homework to work directly with their family on completing the quiz, www.myfootprint.org. The quiz asked questions related to lifestyle choices they and their families make with regard to food, transportation, travel, and their home and energy use. Completion of the quiz resulted in each student receiving a planet score based on his or her use of resources. Students discussed the results the following day in class. I asked the students what questions were asked and put them into categories on the board. Students were then presented with the assignment of designing a sustainable home. Students were asked why these categories were important and if these would help with research related to their project.

During the second stage of the design process, students used the categories from

the *myfootprint* quiz to create a graphic organizer of two column notes (see Figure III.4) to guide their research. Figure 4 demonstrates an example of the graphic organizer. Students worked directly with the teacher librarian to complete the research. The students were given two websites to start their research: www.dreamgreenhomes.com, www.ecofriendlyhouses.net. After the students had a basic understanding of the vocabulary involved in sustainability, the teacher librarian had students practice search strategies for searching and evaluating websites. Students then had to find two more websites to add to their notes using skills practiced with the librarian upon introduction to the research component of the lesson. Some of the more useful sites listed by students included: <http://greenliving.nationalgeographic.com/ecofriendly-ways-build-house-3159.html>, <http://www.childrenoftheearth.org/green-building-sustainable-homes/green-homes-sustainable-living-index.htm>, or http://www.nrel.gov/sustainable_nrel/rsf.html.

2 Column Notes

Factors	Specific Examples with Explanation
Energy	
Heating/Cooling	
Food	
Water	
Transportation	
Furnishings	

Materials	

Figure III.4 2 Column Notes

2 column notes are a graphic organizer to aid students in organizing their research data.

I guided the students through the research using the following questions: (a) How did the designers address sustainability in the examples given?, (b) what are the common factors the homes and websites addressed to make the home sustainable?, (c) What questions did the website www.myfootprint.org ask?, and (d) How could these factors be addressed in the design? Students discussed their findings in a large group discussion format and developed criteria for a sustainable home design.

In the next stage, exploring possibilities, students examined “green” buildings in use. The film *Green Architecture: Environmentally Friendly Housing* chronicled the process of a solar home design competition for university students. The film included some of the items in students’ research, but also demonstrated a few factors not listed on the websites students viewed. Notable to the students was the use of recycled materials. One home used recycled steel of varying colors for the exterior of the home. Another factor was the placement of the home, primarily north and south to take advantage of the lighting and cooling. East and west-facing homes tend to heat up too much in the summer, forcing the use of more air conditioning. A third proposal students reflected on was the use of solar blinds. The students had difficulty thinking of the use of solar beyond solar panels so this innovation helped begin the discussion of incorporating

sustainability into the design of the home. The architects would later discuss this concept.

The class also examined architects and buildings that address sustainability. The California Academy of Sciences, a sustainable museum and research facility, was one of the examples. The building used the sand dug up at the site for dune restoration, as well as recycled denim insulation and a sod roof. Students also read and discussed a Chicago design competition for low income housing that required proposals to be sustainable. The students commented on using wood from certified forests, building rooms of standard building material lengths, designing for air movement so as to eliminate the need for air conditioning, and using large amounts of insulation.

Finally, students examined the work of Frank Lloyd Wright and Frank Gehry. These architects used sustainability concepts before these were popular in architectural designs. Notable to the students was using local materials and materials left over from construction sites. These architects planned their design around the existing location.

The fourth stage, refining ideas, required sketches of design proposals. Students used their notes and resources to plan and begin to sketch out design possibilities. They had to design a front and bird's eye view of their home and the location for which they were designing for the dwelling. Students had three locations to choose from, the mountains, suburbs, or the revitalizing neighborhood area near downtown. They also had to list the sustainable factors addressed and how they were specifically addressing them.

The fifth stage, detailing a solution, required a meeting with the instructor. Students met with me to discuss their designs and sustainability features. Most students made changes to their designs and then further discussed their changes with their

instructor.

The sixth and seventh stages, planning the making and then creating, required students to build a prototype in *Google SketchUp*. Students worked to transfer their sketches to the computer. Students could choose to watch several self-paced tutorials to understand the process of building from the outside in or to start working in the software. The students had worked in *SketchUp* in their technology classes the previous year and had some knowledge of the tools, but did not understand how to design a structure from the outside to the inside. Students had to transfer and apply their knowledge of the software to develop their idea.

Stage eight, evaluation was the most effective component of the project. Students met with two guest architects to discuss their designs. This necessitated having to take feedback and make adjustments as needed. In this step students often returned to their sketches and did additional research. When the designs were complete, students had to write concept statements about their designs. The paragraphs they wrote discussed their goal, design features and reasoning behind the sustainable factors. Throughout the project, students periodically added ideas to their concept maps as well.

Students created concept maps of their learning throughout the process using the mind tool software, *Inspiration*. Lesh and Doerr (2003) define models as,

conceptual systems (consisting of elements, relations, and rules governing interactions) that are expressed using visual notation systems, and that are used to construct, describe or explain the behavior of other system(s) perhaps so that the other system can be manipulated or predicted intelligently. (p. 10)

Models allow students the ability to construct their own knowledge and can be used to

assess student learning (Jonassen, 2006). Learners that build and change their models construct knowledge that leads to conceptual change and understanding of what they are learning (Jonassen, 2006). Concept maps included the identification of important features, such as sustainability and design, supporting information of each of the concepts, links between them, and a reflection on the process. As part of their concept maps, students explained their sustainability choices and why they used it in their home. They discussed the feedback they received from the architects and how it impacted their design. They made connections between the architects' feedback and their sustainability choices. They discussed the easy and difficult aspects of their designs. They defined sustainability as it related to their life and what reflect on the class project.

Research and Procedures

Data collection was comprised of two data components, both quantitative and qualitative, to aid in understanding how students used the design process to inform their designs and their understanding of sustainability in an effort to improve instruction.

Qualitative Data

Qualitative data included teacher observations, evaluating student concept maps and the final design solution, architects' feedback, and student reflections. The final product included the design proposal and a paragraph explaining the sustainability factors used in the design of the home.

The concept maps included important factors and relationships defined by students. These provided information on: (a) the students' understanding of sustainability: (b) the solutions students attempted in their designs, (c) their reasoning

behind their choices, and (d) a snapshot of how students began to solve sustainability issues. Concept maps offered a snapshot of the deeper understanding of how learners constructed their knowledge as it relates to the need for sustainability and what connections they made beyond the classroom. Concept maps were evaluated using a rubric (see figure III.5).

Concept Map Rubric

Benchmark	Criteria	Example in Map
Students demonstrate an understanding of sustainability factors and use in design for specific location.	Map demonstrates relevant information from notes, sketches, and other resources.	<ul style="list-style-type: none"> • Specific factors and examples included • Design idea explained • Demonstrated goal
Students evaluate idea effectiveness of design for location.	Map demonstrates links, concepts and reflections that students are able to refine design and identify criteria or evaluate factors that meet needs of design.	<ul style="list-style-type: none"> • Links between concepts described • Factors evaluated for effectiveness and changes made as needed
Students make connections beyond classroom.	Map demonstrates several links or connections with lifestyle choices.	<ul style="list-style-type: none"> • Concepts provide specific examples of lifestyle change • Reflection provides insight into student

Figure III.5 Assessing Understanding of Sustainability

The rubric was used to evaluate student understanding demonstrated in concept maps.

Final products were analyzed specifically identifying how students addressed sustainability in the designs. Students needed to demonstrate the sustainable factors determined in the research. Factors included, energy, heating and cooling, water, transportation, materials, and food. These factors acted as keywords-in-context codes

when analyzing the data. Using keywords-in-context allowed understanding of students' meaning of the words and to determine the degree of student understanding. This also indicated which specific sustainability factors students addressed in their designs, why they chose those factors, and specifically how students addressed those factors in their designs.

Classroom observations were also recorded in a daily journal during and at the end of each class. Observations and subsequent recording included three components, (a) interactions that occurred with students, including student questions: (b) teacher feedback from students' questions and, (c) how students used feedback in the designs.

The last component of data collection was meeting with the students. The teacher met directly with the students to discuss their grades and the ideas in their project. Students reflected on several questions in small groups: (a) What were the goals of the design? (b) What can you tell me about your final design? (c) How did the architects help you with the design? (d) What was difficult and/or easy about this project? This data was added to students' concept statements about their designs. The answers to these questions were recorded and then analyzed using the keywords in context as well as looking for patterns among student answers.

Quantitative Data

Pre and post-tests were administered to get an overview of student understanding of their learning through the unit. The goal was to compare student growth, examine the student understanding of sustainability concepts, and assess learning through the design process. From the beginning to the end of the project the data answered how much growth occurred. Toward that end, students received both a multiple choice and short

answer test of a very limited number of questions. Students completed the test on-line. Student answers were kept confidential. The dependent variable was the post tests on sustainability. Questions on the pre-and post-test included:

Pre-test:

How do you define sustainability?

Why are sustainable practices important?

What choices do you currently make to live more sustainably?

Post-test

After completing the design task, define sustainability.

Why are sustainable practices important?

What factors did you add to your home design to make it more sustainable?

After completing this unit, what life style choices did you make or are thinking about making as it relates to sustainability?

A scoring rubric used to guide data collection was included in Figure III.6. A colleague and I evaluated student response to the questions. Student answers were then correlated using keywords to analyze for similarities and differences in student responses. These were then grouped accordingly. Having two people evaluating student response ensured greater reliability both with the rubric and keyword analysis.

Pre and Post-Test Scoring Rubric

CRITERIA	EXCEED	MEETS	MISSED/NOT YET
Benchmark #1			
Definition of Sustainability	Definition address the following: The allocation of resources does not allow for depletion, maintenance of the environment, and conservation.	Definition meets one of the requirements: The allocation of resources does not allow for depletion, maintenance of the environment, and conservation.	Definition does not meet either of the requirements or uses the terms: eco-friendly or green ideas.
Importance of sustainable practices	Listed three reasons for why sustainable practices are important.	Listed two reasons for why sustainable practices are important.	Listed one reason for why sustainable practice is important.
Benchmark #2			
Sustainable factors included in design.	Addressed sustainability factors in design: <ul style="list-style-type: none"> • energy, • materials, • water, • food, • transportation, furnishings 	Addressed all but two sustainability factors in design: <ul style="list-style-type: none"> • energy, • materials, • water, • food, • transportation, furnishings 	Addressed two sustainability factors in design: <ul style="list-style-type: none"> • energy, • materials, • water, • food, • transportation, furnishings
Benchmark #3			
Lifestyle changes	Offers at least three options as to lifestyle choices that have changes since lesson	Offers two options as to lifestyle choices that have changes since lesson	Offers one option as to lifestyle choices that have changes since lesson

Figure III.6 Scoring Rubric

Evaluation of student answers was completed using rubric. A cross analysis by the school librarian and instructor was used to ensure reliability.

Student answers were also evaluated using key words in context. Key words in context provided a framework for commonalities among student responses.

The internal validity of the study was supported by linking quantitative evidence of student learning to qualitative examples. Pre-and Post-tests offered a snapshot of student growth when analyzed using the rubric, Figure III.6. However data mined from student reflection and concept maps demonstrated specific examples of how students

used sustainability concepts in their design and why. This same data provided insight into specific ways of how students began to rethink applying sustainability concepts to their own life. The students gave specific examples of lifestyle changes they made after completion of the unit in both reflections, post-test answers, and some students added it as part of their concept maps.

CHAPTER IV

FINDINGS

Research Findings

The main question guiding this study was, How can a home design project impact middle school students' understanding and appreciation of sustainability? Before undertaking the study I thought the students would learn problem solving, apply research, and use knowledge gained in math and in the project. The results demonstrated a greater degree of understanding and application of sustainability concepts and a change in student perceptions than previously understood. As the unit developed from simply completing a project to the use of the design process to guide problem solving, student conceptual change in understanding sustainability became of larger importance. The research into student understanding of sustainability followed a similar path from simple to a more complex understanding. Six sub-questions guided the research: (a) What are middle school students, attitudes and understanding of sustainability before and after a design unit?, (b) Why are sustainable practices important?, (c) After completion has the project impacted students' ideas about personal lifestyle choices in terms of consumption?, (d) What sustainable solutions do students propose for home design?, (e) How do students approach and try to solve sustainability issues in the architecture project?, (f) How did students apply sustainability ideas in their design and why did they make those specific choices?

Student Understanding of Sustainability

The first question, "What are middle school students' attitudes and understanding of sustainability before and after a design unit?" was examined using pre-and post-tests.

Students completed a pre-and post-test in an effort to understand overall student growth regarding the basic concept of sustainability. A rubric, figure III.6 shown in Chapter 3 was used to evaluate both pre-and post-test responses. Pre-and post-tests were evaluated by the teacher and librarian to maintain objectivity in evaluation. Pre-test results demonstrate students had limited to no understanding of the concept of sustainability. Question one, “How do you define sustainability?”, 48 (96%) of the students received a rating of *missed* or *not/yet* based on the rubric. Thirty-three (66%) students defined sustainability as something durable, 11 (22%) defined it as something that can sustain life, 2 (4%) defined it as materials needed to survive where you live, and 2 (4%) had no clue. Two (4%) of the students were able define sustainability as the use and reuse of resources wisely and to keep them from ending in a landfill, receiving a *meets* rating based on the pre and post-test rubric.

Post-test scores, “How do you define sustainability?”, showed considerable growth in student understanding. Thirty (60%) of the students were able to meet at least one objective of the definition. Those 30 students defined sustainability as “not harming the ability to live in the environment” and/or “not taking away from the environment.” Twelve (24%) students gave specific examples of sustainability practices and were able to define it with two or more components from the rubric, thus receiving a rating of *exceeds* according to the rubric. Four (12.5%) students gave specific examples of sustainability and two (4%) specifically defined it as a balance in the use of resources, receiving an *exceeds* rating.

Concept maps also demonstrated student understanding of sustainability. All of the students (100%) were able to define and apply sustainability as it related to their

home design. Seven (14%) students explained sustainability as it related to their home design with specific examples such as, “The location greatly impacts the design. We choose durable materials that would blend in with the location since we are in the mountains.” Ten (20%) were able to explain that they designed their home to conserve water and energy for sustainability purposes. Specifically, “Our smaller home design uses less energy, or “We attempted to design a home that uses less water and energy.” Twenty-students (44%) explained specific sustainability concepts they addressed in their homes. These varied by location and student goal. One group specifically addressed why they choose solar energy, “We used solar to address energy use in the house.” Another stated they used maximum insulation to impact heating and cooling.” Eleven (22%) students all had a wide range in their explanations for sustainability in their homes ranging from specific design elements to practicing sustainability as a lifestyle.

Importance of Sustainability Factors

Question two “Why are sustainable practices important?” was also difficult for the students on the pre-test. Forty-six students (92%) were not able to meet the expectation of listing two or more reasons why sustainability practices are important, there by receiving a *not yet* rating and four receiving a *meets* rating. Student responses were similar to the definition of sustainability. They reasoned the durability was why sustainability was important. Twenty-seven (54%) students stated sustainable practices were important, “for things to last longer.” These students believed sustainability as something durable rather than use of resources. Ten (20%) students reasoned it was important to sustaining life or sustaining an object. Seven (14%) answers varied from having no idea to “it is just important” with no reasoning. Six (12%) students were able

to correctly address two reasons sustainability practices were important.

Post-test results showed a large amount of growth. Twenty-three (46%) students received a *meets* rating, up from three students on the pre-tests. Seventeen (34%) students received a rating of *exceeds* compared with one student on the pre-test and ten (20%) students received a *not yet* rating compared with forty-six on the pre-test. Twenty-four (48%) students reasoned that sustainable practices were important for a healthy environment and planet. This desired outcome included the need for less pollution in order for future generations to have good environment in which to live. Twenty two (44%) students reasoned it was important to use resources wisely and to allow for future generations to also have resources available. Three of these students felt sustainability practices were important because there is a growing population on the planet, which would limit available resources. Three (6%) believed it was important to rethink current practices in terms of home design and construction and one (2%) believed it was important to save and conserve energy. Students made steady progress from reasoning that sustainability was not only about sustaining life but also the wise use of resources, allowing for the health of future generations.

Table IV.1 demonstrates student growth. Table IV.1 Pre and Post-Test Data

The table compares pre and post-test growth.

Question	Pre-Test	Percentage Meeting or Exceeding	Break-down of answers	Post-Test	Percentage Meeting or Exceeding	Break-down of Answers	Growth Percentage
Definition of Sustainability	2: Meets 48: missed/not yet	4% 96%	33 (66%): durability 11(22%): sustain life 2(4%): survival 2(4%): no clue 2(4%): using resources wisely	20 exceeds 30 meets	40% 60%	30(60%): not harming environment 12(24%): defined following rubric 4(12.5%): specific example 2(4%):balance of resources	100% meets or exceeds, 96% growth
Importance of Sustainability Practices	46 missed/not yet 4 meets or exceeds	92% 8%	27(54%): last longer/durability 10(20%): sustaining life 7(14%): no idea or just that it is important 6(12%): able to address why sustainability was important	17 exceeds 23 meets 10 not yet	34% 46% 20%	24(48%): healthy environment and plant 22(44%): preserve resources for future generations 3(6%): home design and building 1(2%): conserve energy	80% meets or exceeds 72% Growth
Change in Lifestyle	27 not yet 13 meets 10 exceeds	54% 26% 20%	27(54%): doing one or nothing to address sustainability 13(26%): 2 practices 10(20%): 3 or more practices	25 exceeds 17 meets 8 not yet	50% 34% 16%	25(50%): 3 or more practices 17(34%): 2 practices 8(6%): doing one or nothing to address sustainability	84% meets or exceeds 38% overall growth

Data analysis of concept statements also showed considerable student reflection in the importance of addressing sustainability. One reflected, “Designing the home has proved rather challenging at times, but has enlightened me to the idea of trying to live environmentally conscious so that our planet is livable for everyone.” A student stated, “This project helped me understand what kind of house I might like to have in the future.” Some had simpler reflections, “We must adjust our way of life to live more sustainably,” or “I started to think about my consumption habits.” Another response from the students was, “These ideas are very important because it can help save the earth,

increase people's health, and create a better world for future generations.” Lastly, one student wrote, “Sustainable practices make the planet a healthier place to live.” Students were not asked in the concept statements to reflect on the project, but those who did demonstrated insight as to why they believed sustainable practices were important.

Changes in Lifestyle Choices

The third research question was “After completing the project, has it impacted students’ ideas about personal lifestyle choices in terms of consumption?” The data from pre-and post-test student responses demonstrated transfer of their project experience to their own personal lives. Prior to the start of the unit, pre-test results demonstrated that 27 (54%) of the students offered one or no options in lifestyle choices in terms of sustainability, receiving a *not yet* rating. Thirteen (26%) students offered two specific options of sustainability practices that they currently make, receiving a *meets* rating, and ten (20%) students offered three or more options, receiving an *exceeds* rating.

Post-test results demonstrated significant growth. Twenty-five (50%) students actually began to practice at least three specific lifestyle choices related to sustainability. Seventeen (34%) students began two specific practices and eight (16%) students had one sustainable practice. Eight (6%) students did not make any choices that were different. Students’ specific practices ranged from recycling, to conservation of water, to conservation of energy.

Data mined from student reflections revealed similar information. Forty-one (82%) students said they started to make changes. Those changes most often included water conservation such as shorter showers and not brushing teeth with the water running, cited by 30 (60%) students. Energy conservation was cited by ten (20%)

students, specifically turning off lights or unplugging appliances and equipment when not in use. Ten (20%) students also cited food choices such as buying local products and/or trying to buy products with less packaging. Recycling was also a large component. When surveying the class prior to the assignment, teacher observation notes indicated that less than 30% of the students in the class recycled, while upon completion of the project 40% said they were trying to recycle. Walking and biking to school were also cited by four (8%) students as ways to conserve after the project. No students cited this in the pre-test. Three (6%) students said they did nothing different. Interestingly, these same students felt it was too expensive to alter lifestyle patterns. These same three preferred purchasing solar panels and wind turbines for energy, rather than conserving by turning off lights and/or unplugging appliances when not in use. They reasoned that they needed to add things to their home, rather than consume less, which was often part of the discussion. Six (12%) of the students said they would employ sustainable practices in the future when they were living out of their parents' home. They stated that they would add things to their own home, such as solar, insulation and energy efficient windows. These students also felt sustainability often required adding "stuff" to their home rather than altering some lifestyle choices. The difference in numbers indicates several students had multiple answers.

Since students were creating a house from scratch, it was difficult for some to think of how to transfer what is discussed and applied in class to specifics in their own life. Examples for specific lifestyle changes were specifically discussed in the *Story of Stuff* movie, the *myfootprint* quiz, and accompanying class discussions. Specific examples given in these sources ranged from lowering consumption rates to recycling.

Water conservation was often cited as a factor students started to address, and specifically taking shorter showers, using only what is needed, not irrigating landscaping, and turning off water while brushing teeth. Energy conservation included turning of lights, lowering the thermostat in winter and raising it in summer, as well as using renewable energy if possible. Food conservation included buying locally produced goods. However many of the examples provided in the resources were seen in student reflections and post-test answers.

Student Proposed Sustainable Solutions

The fourth question, “What sustainable solutions did students propose to home design?” Students answered this question on multiple levels. Students were required to complete a concept map of their designs. One of the components of the concept map required students to reflect on the sustainability factors used and why they were used, as well as the goals of their design. Students also conducted research compiled in a graphic organizer of two column notes. Using their data from research, they were required to complete a sketch of their ideas for a specific location with a listing of sustainability factors. Students selected their best design and discussed their design with the instructor. With the instructor, students evaluated their designs based on the sustainability factors and feasibility of their designs. Students set out to complete their designs using *Google SketchUp*. They met with the architects for further evaluation of their designs. Students then completed a final design proposal and a concept statement describing their design and sustainability factors used.

The use of the design process to help students solve the problem makes it important to understand how students approached and tried to solve sustainability issues

in the architecture project. Teacher observation notes indicated all of the students set out to design a sustainable home, as that was the design problem given.

After completion, students reflected on their designs. Surprisingly and unexpectedly, reflections indicated 50 (100%) of the students began with personal goals for their designs. Specifically, seven (14%) of the students responded that the primary goal of their design was to address living needs for a family while creating a sustainable home. These students set out to create a home that they would want to live in, see figure IV.7 for a student example.



Figure IV.7 Student Example 1

This student example employed the use of small home design with the goal of designing a home they would want to live in. The student also addressed furnishings on the inside of the home such as under floor heating, energy efficient appliances, and the use of non-toxic paints and glues.

Five (10%) of the students responded their primary goal was to use renewable energy as part of their design. Four (8%) of the students responded that their specific goal was to address sustainability needs based on the location they had chosen for their design, see

figure, IV.8.



Figure IV.8 Student Example 2

This group addressed the multiple sustainability factors for a home in the suburbs.

Seven (14%) students had a specific design goals related to the look of the house, or to a specific feature of the space, see figure IV.9.



Figure IV.9 Student Example 3

This student proposed design demonstrates the use of a goal focused on using different shapes than the standard square or rectangle.

Ten (20%) students set out to address water or energy usage. Three (6%) believed in building small structures. Twenty two (44%) students had the same goal of the design problem, to simply address sustainability in their design (the difference in numbers is that several students had multiple goals). Students with a goal that went beyond sustainability, such as designing a small home for a family or for themselves, had designs that were more successful in terms of overall quality and demonstration of understanding of sustainability. This was further supported by the architects upon reflection. The architects specifically stated having students set a goal beyond sustainability would help to improved designs. Student example of this is seen Figure IV.10 and IV.11.



Figure IV.10 Student Example 4

This student proposed design demonstrates sustainable design through the goal of designing a smaller home, 500 square feet, roof top gardening, and the use of electric car.

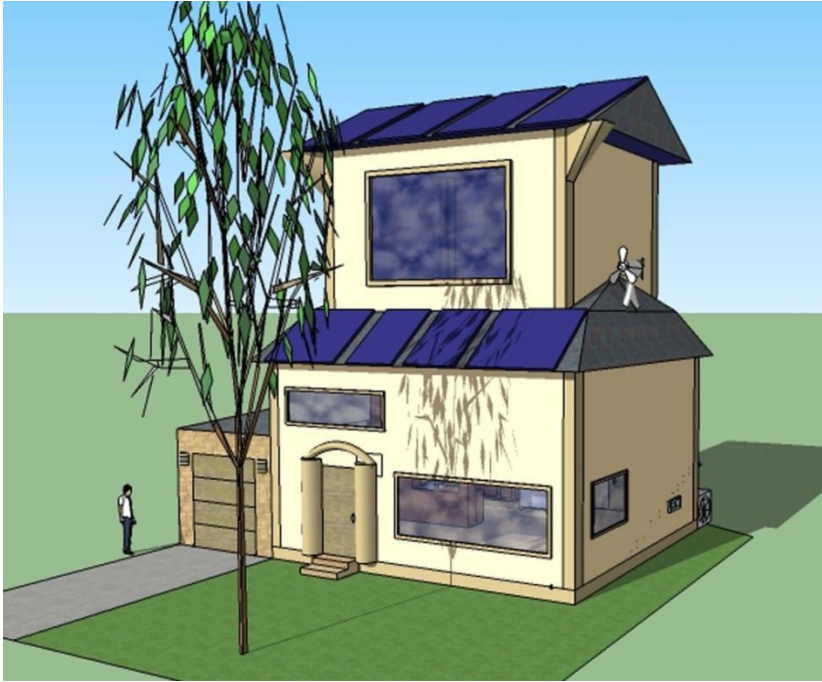


Figure IV.11 Student Example 5

This student proposed design demonstrates sustainable design through the goal of designing a smaller home and the use of two energy sources, wind and solar.

Making Choices about Sustainability

Many students could easily pick sustainable products and place them in the home because of their research. They had greater difficulty in determining which would work best for their location and their personal goals for their design. The fifth and sixth questions were examined using student reflections, concept maps, discussions with the architects and concept statements. So exactly how did they apply sustainability ideas in their design, and why did they make those specific choices? Also, how do students approach and try to solve sustainability issues in the architecture project? The first thing that is evident is that the students applied research from their two column notes into their designs. This is supported by the architects' visit and reflection with the teacher.

Teacher observation notes indicate that the architects stated most of the students were able to easily apply sustainability concepts in their designs, but didn't often understand why they needed certain things and what other possibilities were available, referred to by the architects as "lick-and-stick" design. As a result of the architects' evaluation, the instructor worked directly with students to help them understand why they needed to address sustainability factors and what would work best with their design. This work is evident in student concept statements about their homes. Students addressed energy, heating and cooling, food, water, transportation, and building materials. While furnishings, square footage, and area were discussed and important, these were the two most difficult aspects of designing for the students. Square footage requires students to pay attention to scale and transfer of knowledge of math concepts in a new setting, which as stated previously, was a difficult concept for students. Secondly, most of the sustainability factors can be addressed on the exterior rather than the interior. Students had the most fun building interiors, but generally ran out of time. Several groups ran out of class time to complete the inside of their home. Forty-eight (96%) of fifty students were able to discuss addressing six or more or more of these factors into their designs.

The class also spent time examining the works of famous architects such as Frank Lloyd Wright and Frank Gehry. It is evident that several of the students used similar ideas in their designs. In several of Frank Lloyd Wright's designs, he used materials from the building site in the building and furnishings. Frank Gehry used materials left over from construction sites for his own home, thus repurposing materials. Fourteen students indicated the use of local materials from the building site be used in the construction or furnishings of their own. Ten (20%) different students cited the use of

repurposed materials in their furnishings or materials.

The students also examined the green architecture proposals from a Chicago city design competition and discussed the video, *Green Architecture: Environmentally Friendly Housing*. Some of the design ideas presented included the use of higher ceilings, placing two windows per room to reduce the need for lighting, sod roofing, wood from certified forests, non-toxic paints and glues, durable materials, and avoiding costly air conditioning by designing homes to maximize air flow. The video chronicled a solar home design competition for university students. It emphasized the importance of placement of a home, primarily north and south, recycled materials, and alternative ways to use solar in the design. Thirty-one (62%) students cited the use of one or more of these ideas in their designs. While students discussed these ideas in class and added them to their notes, they did not spend as much time working with these ideas as they had done with the initial research. It is a significant outcome to see that so many students used one or more of these ideas in their designs. Table IV.2 further breaks down student application of research.

Table IV.2 Demonstration of Student Learning

This table further demonstrates student learning and the students application of the research in their designs.

Data Source	Factors Addressed	Examples	Confirms Learning
Concept Maps	Energy	Solar, wind for the Number of sunny days	Cited by 46 students
Designs	Materials	<ul style="list-style-type: none">• Size of home because of use of less resources• Local materials if mountain design	Cited by 18 students
Reflections	Conservation	Low flow showers and toilets, energy efficient appliances	Cited by 26 students
Concept Statements	<ul style="list-style-type: none">• Materials• Food	<ul style="list-style-type: none">• Stone and brick for durability• Greenhouses, gardens and food delivery based on location	Cited by 46 students

Students' design goals often drove some of the sustainability factors included in their designs. A small home design led students to think about how to best utilize the space in their home and incorporate specific design features such as durable materials or passive solar. Materials such as brick and stone were chosen because they are durable. Solar was cited as used by forty-six (94%) of the students because Colorado has abundant of sunny days. Students who chose mountain home designs often also added wind turbines because the architects suggested having more than one energy source whenever possible. Suburban designs that included wind in their plan worked with vertical access wind turbines. The size of the home was a factor in sustainability for eighteen designs. These students explained their design used fewer resources, from building material to

energy use to heating and cooling. Food was another factor addressed by students that varied with location of the home. Mountain designs often contained greenhouses where as suburban designs often contained gardens. Students not interested in growing food discussed the use of grocery delivery and buying at local markets. Conservation played a role in twenty-six (42%) designs. This was evident in the use of low flow showers and toilets as well as the use of energy efficient appliances as part of the designs.

While water, materials, transportation, and heating and cooling were addressed, these considerations didn't vary as much by location than as design choices made by students. Transportation encouraged the use of walking, biking, and public transportation whenever possible or the use of electric cars. Water was addressed often through conservation and catchment systems for watering landscaping. Native materials were considered in that several students with mountain designs did try to use locally grown materials in their home.

The concept statements about student designs further demonstrate insight into their thinking about the project. Several students had some very interesting reflections on the reasons behind their designs. One student stated, "I built this project on this location to help me understand what I needed less of and what I needed more of in the design." One pair of students stated, "We worked on this project for many weeks and when we started off we never really knew about the word sustainable. It isn't just a word because it has a definition that inspires us to think outside the box. Many people could sketch their house and create a model in *Google SketchUp*. But when we took that sketch and created a model, we had to think about the energy sources and materials and ways to make it eco-friendly." Another group discussed the biggest reason for some of their

choices in their design, “We picked stuff that worked well together like natural materials of stone and bamboo and that worked well with in a home for a family.” A rather unique goal was discussed by this student who opted for a small home of about 500 square feet: “The house features great aesthetics including a sharp modern look with the house being based solely on rectangles. I chose this type of design and space manipulation so I could take the least amount of space and resources and still have a comfortable home.” Lastly, one student wrote, “My reason for my design tactics was just to create a simple everyday house that anyone could live in. From there, I simply applied eco-friendly factors to attempt to make the house sustainable. For the most part, I believe it was a success.”

Post lesson reflection by the students on what they learned demonstrated growth in applying sustainability concepts. Twenty-two (44%) students reflected they had learned not only a number of ways to address sustainability in the design of the home, but also ways they can live more sustainably today. They all provided specific examples of items and practices used in the design or on a personal level. Twenty students (44%) discussed learning how to design a home or discussed learning very specific sustainability factors they then applied to their home design. They cited that location made a difference in the sustainability choices they made. Placing solar panels on the south side of the home was essential or choosing a smaller home meant using less resources. Sixteen (32%) students cited understanding sustainability concepts or sustainability in general was a major factor they learned. Several students had multiple listings of what they learned, thus the variance in numbers.

Sketching was another component of the process that students identified as both difficult and easy. Thirty-nine (78%) of students reflected that, sketching and deciding

what factors to address was the easiest part of the process from research to design. They still had specific difficulties with sketching, but overall this was the easiest part of the design process. These students specifically cited that the easiest component of the sketching process was deciding what factors to address in their designs. Seven (14%) of the students' reflections varied from making their designs look appealing to using feedback from the architects or designing for the location as rather easy parts of the process.

The students had difficulties evaluating their own planning sketches. Ten (20%) students designing for the suburbs often included large wind turbines. The teacher asked students if they might want to live next to a wind turbine themselves. Many of the students stated no. They were then given options for alternative types of turbines, such as vertical access turbines that are smaller and can easily be used when houses are in close proximity. These ideas were often provided for the students as they have limited knowledge of actual possibilities. Two (4%), students were also asked where the best place to put solar panels on their home might be. Many had not thought about needing them on the south side of the home, or incorporating solar panels into the design or look of the home. Three (6%) students placing their homes in the mountains often put in gardens as part of their design. I discussed growing seasons and the limitation this may impose. Students often adjusted with the use of grocery delivery, planning for animals or, in the case of one group, adding a larger deck to accommodate house plants in pots. Other considerations included working to buy locally grown produce or adding a greenhouse into their design. Four (8%) students had issues addressing each of the sustainability factors in their sketches for which they had conducted research. The

students worked directly with the teacher to address missing factors and worked to choose the best based on their location.

Another problem students had in sketching was matching the look of their designs with the floor plan ideas. This was observed in both teacher notes and student reflection. Thirty-seven (74%) students cited sketching difficulties such as working with the floor plan, getting the sketch to look the way they had envisioned the home, or mapping out two story homes. The instructor worked directly with students to plan stairs, hallways and placement of rooms based on student designs. This was very important to be done correctly, especially when working in *SketchUp*. For students to be highly successful with their designs, the software required students to design from the outside by creating the basic shape of the house and pushing and pulling shapes as needed for their designs.

Students transferred their sketches to building actual professional-looking proposals with the software. Students were divided about the ease of using the design software. Actually, working in the program was where some students felt the most comfortable. Many cited that was because they worked in *SketchUp* in seventh grade. Twenty-two (44%) of the fifty students responded they felt comfortable working in the program. However, the rest responded that actually making their design work in Google SketchUp was the difficult part. One student explained, “Last year in seventh grade technology class the project required designing an interior space of several rooms. So I at least knew how to use the tools, but had difficulty figuring out how to make the design work.” This project required students to design an entire house, and they started on the outside and worked their way to the inside. It was the opposite thinking process. This was further cited by six (12%) other students who stated the most difficult part was using

what they knew from *SketchUp*, math, and science classes, but in a very different way. Students had to apply knowledge of climate, clean energy, scale, and calculating area. While they didn't call it "transfer of knowledge," these students acknowledged they had to use math and science in a different setting which was difficult for many. This transfer of knowledge represents a higher level skill and was one of the goals of the project.

Another difficulty cited in working with the technology was getting the design to look and work the way students wanted. While students understood the use of tools, they had difficulty understanding how to use the tools to get what they wanted. Once students were working in *SketchUp*, 90% of the instructor's time was spent working directly with students on technical difficulties with their models or using specific tools. In total 36 homes were proposed out of fifty students participating in the study. The difference accounts for the fact that students were allowed to work with partners

Based on teacher observation, students had great difficulty measuring and making the house to scale and then making adjustments as needed. While students learned how to calculate area in their seventh grade math curriculum, they had difficulty applying this skill when asked to do this as part of their new design. Scaffolding by the instructor was provided based on the zone of proximal development of individual students. The instructor worked with students in small groups to review the concept. Next, based on observation notes, students had to measure and calculate the area of their home. If it was too large or small (as was true for eight homes) the teacher taught students how to adjust their designs as needed. Four homes were designed around a specific concept such as a circle. These particular designs required more technical knowledge of the software than the students possessed. Thus, the instructor spent time helping the students work with the

tools to get what they needed. Ten (20%) students had difficulty creating a pitched roof in their design. They were taught how to do this which they then could add to their design. Four groups (16%) worked on their home from the inside first and as a result their homes had to be reworked. The instructor worked directly with these groups and these problems often took most of a class period to fix. The instructor did divide tasks so as to have knowledgeable students teach technical concepts to other less knowledgeable students to free up the instructor's time. The architects were asked not to work with students on technical issues with the software, so that their focus was only on working with the students on sustainability and design.

Students reflected that the difficult part of the design was to decide what specific sustainable components to add for the design and location. Thirty-four (68%) of the students cited making the design work for the location and incorporating sustainability were the most difficult parts. One group summed it up best when they stated, "creating an eco-friendly home was difficult when making choices about what factors to address and how for the location." The specific feedback students received and subsequently discussed in their concept maps was also demonstrated in their final home-design proposals. The architects reported that many of the students applied sustainability components to their design, or specific objects like solar or wind turbines but didn't apply design concepts such as window placement or which direction their home faced. They called this "lick and stick" design. Meaning that students were able to pick from a list of factors and specific items they would put in their home to address that factor, but didn't always understand why or how design can address sustainability itself.

Student reflection in their concept maps supported this awareness. Thirty-five

(70%) students cited feedback from the architects about incorporating sustainability factors into the design of the home as being very helpful. These students specifically noted that the types of windows placed on the north and south sides of the home based on their location were something they changed after the architects input. Ten (20%) of the students stated they had difficulty, “figuring out the placement of solar panels and windows because they didn’t think about determining the north and south in their designs.” These students did make these changes in their designs after the architects’ visit as evidenced in their final proposals. Students whose homes were located in suburban Denver, for example, worked to place larger windows on the north side for light to avoid over-heating in summer. Teacher observation notes also indicated students had difficulty understanding which direction the home was facing and the instructor addressed this by demonstrating how to have the shadows showing while working as well as how to rotate an entire house as needed.

Another common design feature discussed by the architects was adding landscaping around the home (such as bushes, shrubs and shade trees). This was shown to help with energy efficiency, heating, and cooling, as it acted as insulation. The architects suggested this in 6 (12%) of the designs as referenced by the students in reflections. . The architects also discussed incorporating solar panels into the actual design of the house rather than just panels on the roof. An example cited in the video for students was the use of solar window shades. Passive solar was another option for students, but a difficult concept for them to understand in designing. Four (8%) students stated they did address this in the final designs by specifically placing solar panels in overhangs in decking areas.

The architects discussed energy use and subsequently cited by 17 (34%) students was to add more than one energy source into their design. The most common combination was to use both wind and solar as a result of this feedback. Ultimately, 19 (38%) students added solar and wind to their design, and 6 (12%) students decided to use geothermal energy for heating and cooling with solar. This is an interesting phenomenon since nine more of the students added two forms of energy to their designs than discussed with the architects. This could mean students did discuss this with each other.

Summary

After analyzing the data, it was apparent that students started with a limited or no understanding of sustainability concepts. This was further evidenced by the questions and push back received from the video and *my footprint* quiz. Teacher observation notes demonstrated that student interest varied in the beginning. Students asked questions related to how these policies were put into place, how can they be changed to meet the needs of today, and, what can be done to make a difference. Some students pushed back, with statements such as “I don’t really care,” “My parents don’t agree with ecofriendly ideas,” or “I like to have a lot of stuff so I am not going to listen.”

The quiz challenged students to analyze their own and their families’ habits. Students reported their planet scores to the teacher. The class range on average was 4-8 planets would be needed to live our current lifestyle if all people on the planet lived the way the students currently do. Students didn’t comprehend this until the instructor asked the question, how many planets do we actually have to live on? This driving discussion question from the *footprint* quiz opened students to think about their options. Students discussed the questions asked, concerning food, water, transportation, housing and energy

use. They brainstormed ways they currently can make different choices as a class, as evidenced in the lifestyle changes students stated they made.

Upon review of the post data, it was apparent that students were able to understand sustainability and define it in their own words. All of the students, 100%, were able to define sustainability appropriately after completion of the unit. Prior to the start of the unit only 4% of the students could correctly define it. This not only demonstrates a tremendous amount of growth, but also that concept was new to the students, and they were able to grasp and understand after completing the project. More importantly students were able to apply it to their own lives, even if only at a minimal level. They began to think about their personal choices. Design-based learning provided a framework for students to address a rather complex problem-based instruction. It challenged the students to begin to think about the consumption paradigms and begin to provide alternatives.

Students were able to begin to understand how to apply the concepts in their designs and why it was important to do so. The concept statements about their work and the goals each student began with demonstrated a growth in the understanding of the project. Interestingly, not one student proposed a multifamily dwelling. All designs were single family homes with large yards, many with fences around them. This shouldn't be surprising since that is how most of the students in the area live. However, after discussing the use of resources in class and ways to use less, no students were able to go beyond the common single family structure.

CHAPTER V

DISCUSSION

The study began as a means to understand student learning as it relates sustainability and applying sustainability concepts in technology education. The findings were intended to improve classroom instruction. A review of the literature indicates that sustainability is needed in the technology education classroom. Design education framework with the aide of problem-based learning environment and scaffolded instruction were used to address sustainability education. It was proven that this process can create an environment that allows students to question the current paradigms in which they take action to make changes.

The main question, that guided the research, “How can a home design project impact middle school students’ understanding and appreciation of sustainability?” provided a basis for reflection. Design education with the use of technology can be an effective tool for conceptual change. Students began the unit with limited to no understanding of sustainability concepts. Upon completion of the unit all of the students were able to define sustainability and apply sustainability concepts. More importantly, a majority of the students actually applied specific concepts to their own personal lives, thus changing their attitudes regarding the importance of sustainability, further proving conceptual growth.

Design-based education also provided an ideal framework for guiding students through the problem solving. Students were successful in their design proposals. All students were able to apply some of the research conducted in class to their final designs and explain how sustainability concepts were used, both in their concept statements and

reflections. Students were able to directly reflect and evaluate their designs with the architects and make changes as needed. Students also cited this as an important and worthwhile process in their concept maps. The design process also proved invaluable in guiding students through problem solving. Not only did the process provide scaffolding for students, it enabled them to begin to develop problem solving skills that can be transferred into other contexts.

The findings regarding student learning provide support for Vygotsky's theory of learning and development. Students were ready to grasp sustainability concepts, demonstrating a 96% growth rate. Students were able to grasp these concepts with the correct supports, and the unit therefore, was in the zone of proximal development. Dialogue is a key to cognitive development. Students were engaged in a problem solving experience, a key component to learning emphasized by both Vygotsky and Dewey. From this experience students were able to apply sustainability concepts to their designs and internalize goals that were greater than the design problem. They set goals such as creating a sustainable home that a family would actually want or a house they would live in. Students were also able to apply these concepts into their personal lives.

Dialogue is a major component of development and learning according to Vygotsky and Dewey. Students were able to actively participate in the problem solving process through the use of dialogue. More importantly student concept maps and reflections demonstrated the various kinds of dialogue that lead to student learning. Students discussed, reflected and evaluated their work with professionals in the field, the instructor, classmates, and through their writing.. They demonstrated application of research in their designs and concept statements about their work. Their sketches and

final designs often changed as students worked through the problem, demonstrating internal dialogue as well.

Interpretation and Meaning of Findings

When I began this project and the study I expected some growth in student understanding and application of sustainability. However I didn't expect that all of the students would be able to define sustainability, nor actually apply sustainability concepts to their personal life. It confirmed my hypothesis and theoretical framework that problem-based learning environments with adequate scaffolding can be an effective method for delivering instruction that challenges students and is also motivating to lead to overall conceptual change.

Developmentally the group studied consisted of 12-14 year old students and sustainability is a difficult concept. Some parents of students in the school view the need for sustainability as political rather factual, thus making conceptual change a more difficult process for some of those students. The considerable growth in application sustainability concepts shows students open to change, particularly after participating in the design problem.

After completing the project, 74% of the students had made two or more changes in their personal habits related to sustainability. Reflections completed by the students demonstrated 82% of the students did make some changes. Their answers concerning specific habits they changed related to water conservation, saving electricity, walking and riding bikes, and buying local produce. Recycling was also cited by students. This demonstrates the students cared enough after the completion of the project to begin making small, but incremental changes.

Students demonstrated considerable growth in the understanding and application of sustainable solutions to their designs. They were able to propose authentic solutions to the problem and apply their research. Students followed the design process throughout the project. They started with planning sketches, added information from their research and discussed their designs with the architects. Their proposals then changed based on feedback from the architects. Students cited making specific changes to their designs based location and feedback from the architects and the instructor. They also cited using specific ideas from research that they applied in their designs. Feedback by the architects in particular proved to be invaluable to student growth. Students are accountable to the designs when they meet with the architects and must defend their goals and purpose. When students received feedback they immediately changed their designs, but were also able to grasp the importance of getting it right in their designs.

Receiving or accessing information at the moment it is needed further supports the theoretical framework. Students wouldn't always grasp technical concepts or vocabulary until they were needed to complete a task in their designs. It is this time sensitive introduction that is important to note when helping students grasp deeper concepts such as sustainability or problem solving.

Implications

The study has some implications on future instruction in my classroom. I am aware of student difficulties and will address them in classroom instruction. One difficulty cited by the student was transferring the sketch to a design in *SketchUp*. Guiding students through the process by having them draw a simple object and recreate

in *SketchUp* could help. Providing easy access to video tutorials that demonstrate how to use *SketchUp* for common building issues will also be helpful. Working directly with students on drawing to scale and building basic drawing skills may help. This may also provide assistance for understanding and applying the mathematical concepts learned in math class to the technology classroom. Students had difficulty applying these concepts when needed. Teacher review and small group instruction were used in class, and did help the students. More review is needed in how to help students with this thinking process.

Another interesting aspect that emerged from the data was that students could use sustainability concepts in their designs from their research, but didn't always understand why they used them or the benefit based on location. This is a critical component of the process and a higher level thinking skill. Direct work with students on understanding how sustainability can be accomplished through design is needed.

Data from teacher observation notes also indicated a large amount of instructor time was helping with technology issues. The focus really should be on working with student designs and discussing their ideas. Creating an easily accessible database of videos for students may prove to eliminate some of this time. The study also demonstrates students are able to handle sustainability concepts at this age and apply these to their own lives.

Implications for Technology Instruction

Technology education needs to be more than teaching software. Sustainability education can be a valuable part of a middle school technology curriculum as the concept

goes beyond the teaching of software. Rather it enables to teachers to address current issues, connect learning beyond the classroom and provides problems that challenge students to think beyond their comfort zone. The use of technology enables quick access to resources and software that enables students to create final designs that look professional. The study provides a case that technology education leading to conceptual change needs to be about problems that go beyond software. Attributes from problem-based learning help set the stage for higher level concepts such as sustainability that lead to the conceptual change desired. Providing adequate scaffolding through the design process and helping students through research tasks and organizing their information is also an essential component.

Sustainability can be addressed in the classroom through a variety of problems and projects. Reaching out to professionals working on current issues is an ideal way to develop problems that help students connect learning beyond the classroom. The architects in this study have proved to be invaluable in the development of the project, the scaffolding of the lesson, and interventions students needed. Professionals working directly with the students enables them to understand that the classroom expectations for the problem are not different than tasks preformed for specific careers.

Building problem-based tasks takes time and is a learning process. Design experiments provide a guide for building instruction that includes reflection and understanding of how classroom elements contribute to student learning and understanding. Using design experiments as a guide can aid instructors in developing higher level lessons that build knowledge and conceptual change. Instruction varies by

grouping of students. Design education and the design process allow for flexibility in addressing student needs.

Implications for Design-Based Instruction

This study provides support for the effectiveness of design-based instruction as an approach to raising the understanding and appreciation of middle school students for sustainability while building technical and conceptual knowledge and skills. The design process is an ideal vehicle to guide students through when examining difficult problems and creating solutions. Sustainability, while a difficult concept, can be understood by middle school students with the help of facilitated instruction. It follows the principles of the zone of proximal development. Experiential learning allows students a hands-on working environment in which to explore ideas, discuss and reflect on ideas, and apply knowledge. The findings from this study demonstrate the sustainable architecture design problem is an effective lesson that meets the needs of learners, but challenges them to think differently while they apply previous knowledge.

The work with professionals in the field also proved to be an invaluable component to the lesson. The professionals gave authentic insights into the students' thinking and process allowing me to address student needs. They also gave feedback on the lesson, offering suggestions for improvement and different ways to focus the lesson depending on learning objectives. The architects provided valuable resources and information related to design, sustainability and working with architecture to aid in instruction and learning.

Implications for Research and Further Questions for Study

Understanding how students thought about their designs through interviewing would be of interest. Continuous improvement of curriculum and teaching on sustainability at the middle school level would be helpful as there are limited studies currently available. The results of the study will be used to improve the instruction of the research component of the unit. However, some questions need to be discussed further. Are students able to carry their understanding of sustainability beyond one lesson or for a temporary amount of time? Are students able to apply the design process to other problems they encounter in both technology and core classes? Do other design based projects that address sustainability have similar impact on student learning?

Limitations

The study had some limitations. Student work was the primary data source. A large portion of the study included the evaluation of student writing through concept statements, answers to pre-tests, and reflections. Data can be limited if students are not comfortable writing. Several students were absent during the last week of the project. Five students between the two classes were absent for an entire week. This made getting their work completed as well as working and meeting with them about their project difficult, and had they not been absent their reflections and post-test answers may have been different. This study only evaluated student learning during a project with a small sample size. This may make it difficult to apply to a larger setting.

Design-based instruction should not be reserved for the art or technology classroom. Students who build skills for the 21st century need more experience with problem-solving and problem-solving processes. The science classroom can provide

high quality problems that require more in-depth study than the scientific method. The design process is but one example. Educators no longer the luxury of not addressing sustainability concepts in any school curriculum. School curricula that creates learners who question the current paradigms compel other subject areas to address these concepts in instruction and in school-wide practices. Students can and are willing to apply sustainability concepts in their own lives when presented with problems that help begin conceptual growth.

The project allowed students to begin questioning current paradigms and consumption patterns, creating learners who are building their critical thinking skills while addressing the needs and interests of middle school students, using technology. The study gave a glimpse of how students address sustainability factors in their own designs, how students apply research knowledge into a design problem, and that hopefully students can begin to take what they have learned in a classroom setting and apply it to their own lives.

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